PERIODIC ACTIVITY OF COMET BRADFIELD 1987s

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Abstract. A periodic brightness variation of about 6 days was found by applying maximum entropy method to the visual brightness of Comet Bradfield 1987s. This activity was clearly apparent in January of 1988. No other outstanding period was detected. This suggests that the period of the rotation or precession of the nucleus is about 6 days.

Comet Bradfield 1987s was discovered as a diffuse moving object by W. A. Bradfield on August 11, 1987 (McNaught, 1987). Because its total visual magnitude increased up to about 5th, many amateur astronomers observed this comet. The number of the magnitude estimates of Comet Bradfield 1987s assembled by 'Hoshi-no-Hiroba', which is the Japanese group of amateur astronomers interested in comets, is 873 from August 16 of 1987 through February 21 of 1988. These observations were carried out by 60 members in 'Hoshi-no-Hiroba'. This comet showed significant night-to-night variation in the visual brightness from its early stage (Bortle, 1988). We tried to find out the periodic variation from these visual brightness measurements.

The data of magnitude estimates contain serious errors systematically caused by the difference of observational conditions. The major source of the error is aperture effect of the telescope used for the observations. This effect was investigated empirically by Bobrovnikoff (1941a, 1941b). He proposed the correction formula as

$$M = M_{\rm obs} + \Delta M\,, \tag{1}$$

with

$$\Delta M = -0.066 \Delta a\,, \tag{2}$$

where M is the total magnitude corrected to that of naked eye, $M_{\rm obs}$ the observed magnitude, ΔM the aperture correction, Δa the telescope aperture in unit of cm. Meisel (1970) showed semi-quantitatively that this empirical formula represented an acceptable statistical compromise with theoretical formula. The correction factor for the reflectors was found to be less than one-third of the Bobrovnikoff's value by Morris (1973). He obtained the following aperture corrections reduced from about 700 observations as

$$\Delta M = -0.055\Delta a \tag{3}$$

for refractors, and

$$\Delta M = -0.019\Delta a \tag{4}$$

for reflectors, respectively. Meisel and Morris (1976) recommended that the aperture correction should be performed separately for refractors and reflectors. In this study, we corrected each observed magnitude by applying Equations (3) and (4) together with Equation (1).

The conditions of meteorology and light pollution depend on the observation site of each observer. Hence, these effects can be included in the personal equation as well as those of personal experiences. The error caused by the personal effects are thought to be systematic. To remove this, we made use of the global brightness variation with the heliocentric distance as

$$M = M_0 + 5\log\Delta + K\log r, \tag{5}$$

where M_0 is the absolute magnitude of the comet, Δ the geocentric distance, r the heliocentric distance, and K the coefficient of the magnitude dependence on the heliocentric distance (Meisel and Morris, 1982). Because Δ and r is known, we can obtain the M_0 and K by the least square fit to a straight line for each observer. Let $M_0(\mathrm{A})$ and $K(\mathrm{A})$ be those of observer A. Then the magnitude difference $\Delta M(\mathrm{A}-\mathrm{B})$, which is caused by the personal effect between observers A and B, is written as

$$\Delta M(\mathrm{A}-\mathrm{B}) = M_0(\mathrm{A}) - M_0(\mathrm{B}) + (K(\mathrm{A}) - K(\mathrm{B}))\,\mathrm{LOG}\,r\,. \tag{6}$$

Therefore, the personal effect of observer B relative to observer A can be corrected by adding this term $\Delta M(\mathrm{A}-\mathrm{B})$ to the aperture-corrected magnitude of observer B. The personal effect correction was carried out relative to a specific expert observer A. We selected J. Kobayashi as the observer A, because of his vast quantity of observations. In this process, the data of 425 measurements are rejected since the K has the opposite sign due to the limited number of their observations. It must be noted that the selection of the observer A does not influence the final result in this study. When another observer is selected as A, only the global structure of the brightness variation with heliocentric distance will be changed. The result of the periodic analysis depends on the relative fluctuation of the magnitude, not on the global variation of the total magnitude.

The effects of moonlight and airmass were neglected, since these correlations with the estimated magnitude is not strong (Meisel, 1970). If different comparison stars are used in observations among observers, it may also produce the error of estimation. The comparison stars around the comet were selected by the 'Hoshi-no-Hiroba' in advance, and their magnitude data were supplied to all members. It is regarded that the same comparison stars were used by all members.

Applications of the different methods for magnitude estimation may produce the systematic error. There are a few methods to measure the total visual brightness in assembled data. One is the Sidgwick's method, which is to compare the image of on-focused comet with those of the out-of-focus stars in the telescope. One is Bobrovnikoff's method (Bobrovnikoff, 1941a), which is to compare the image of off-focus comet with those of off-focus stars. The other is Beyer's method (Beyer, 1952), which is to observe relative extinction of out-of-focus star and the comet image. In the assembled data, half the observers applied Sidgwick's method, and the one fifth Bobrovnikoff's method. Because Beyer's method is quite sensitive to the sky background illumination, it was adopted only by a few observers. Some of the measurements were carried out by unknown methods. Meisel (1970) demonstrated that the Bobrovnikov's and Sidgwick's methods produced a flux mismatch in the focal plane. Meisel and Morris (1976) commented that the systematic effects are minimized if images were placed out-of-focus by the least amount necessary to make the extended object look similar to the star. To find out the effect of the applied methods, a data set, which consisted of the measurements only by the Sidgwick's method, were selected for additional analysis.

After these corrections, the standard deviation of the measurements on the same night is typically ± 0.2 mag. Because the time of the observations of this comet was limited to a few hours every night, this standard deviation is not due to the intrinsic variation of the comet's brightness. Then we consider this standard deviation as a random error of the brightness measurements. Hence, we averaged the measurements which exist within one standard deviation among all measurements on the same night, and used the averaged value as a daily representative for the analysis. Figure 1 shows the average magnitude along with the standard deviation on each night. The data of the dates on which no member observed this comet are compensated by the linear interpolation.

A maximum entropy method (hereafter MEM) was applied to find periodic component. The MEM has a high sensitivity of the frequency detection even if the number of the sample data is not enough (Burg, 1975). The width of the window used here was 30 days, and moving step was 2 days. The dynamic spectrum of the MEM from 448 observations is shown in Figure 2. Figure 3 is the same as Figure 2 but of the data of 395 measurements obtained by the Sidgwick's method only.

Both figures show clear periodic activity of about 6 days. It appeared at the end of December in 1987, and continued to the end of January in 1988. Although the component of about 3 days period is shown in Figure 3, this is not so strong as 6-day period. In Figure 1, the local brightness peaks can be indicated around on December 30, January 6, 11, 18, and 27. Except on January 27, three intervals of four local peaks are all 6 ± 1 days. The detected periodicity by MEM is essentially due to these brightness peaks. Some observers commented that central part of the coma condensed on these nights. This characteristic is the

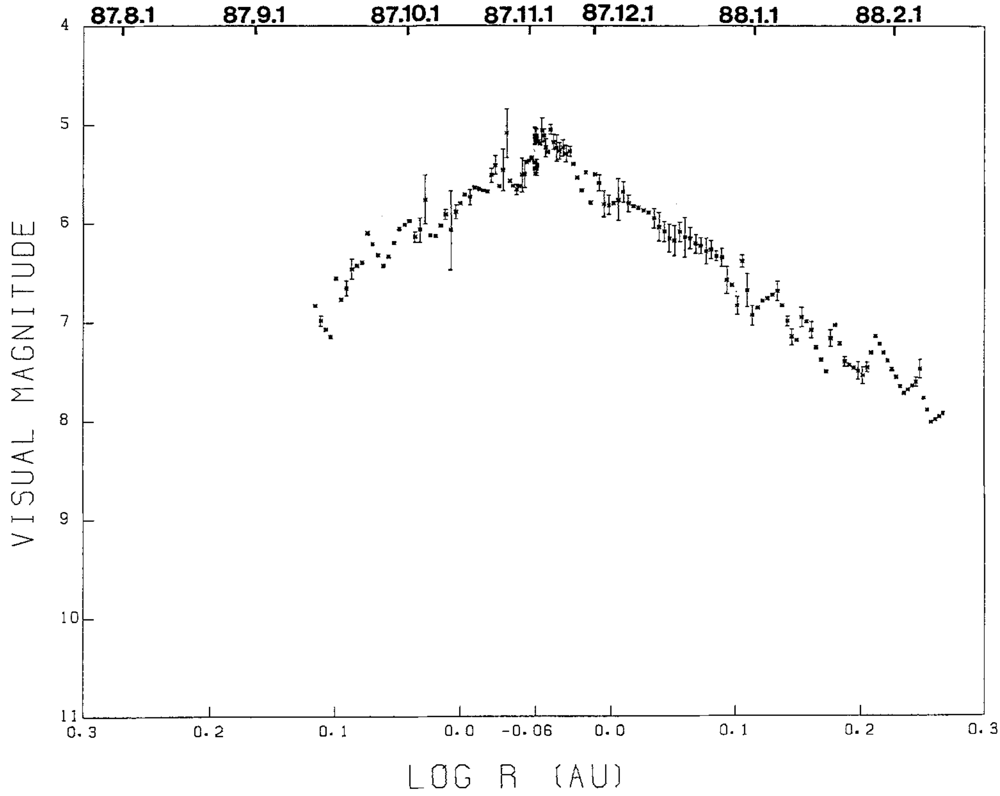

Fig. 1. The brightness variation of Comet Bradfield 1987s. The abscissa is the log heliocentric distance along with the dates of observations indicated in the upper part of the figure. The ordinates is the corrected total visual magnitude. The magnitude is plotted with the standard deviation. No standard deviation is plotted in case of only one observation or the result of the interpolation.

same as that of the 7.4-day periodic outbursts of Comet P/Halley (Watanabe, 1988). These facts suggest that this periodic activity is caused by the outburst of a specific active region on the nucleus surface, and that the period is attributed to the rotation or precession of the nucleus. The corresponding peak next to that of January 18 is not clear. Although the peak of January 27 is outstanding in the figure, we cannot say positively that this is a true local brightness peak because of the lack of observations. The variation of the linear declining brightness from January 28 through February 3 is the result of the interpolation.

No outstanding period is detected until the December of 1987. This situation suggests that the active region could not be illuminated by the Sun. The geometrical relation between the acive region and the Sun was changed with the orbital motion of the comet. Hence, it is possible to think that the active region

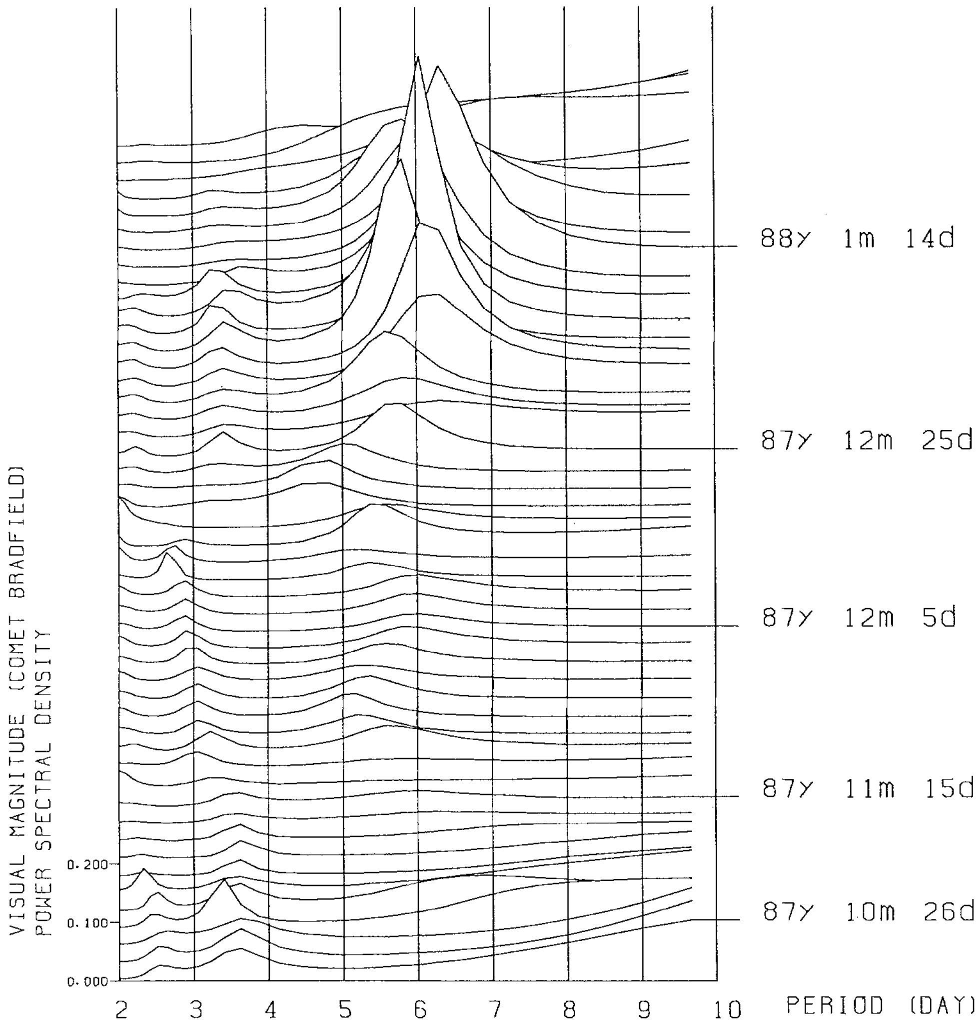

Fig. 2. The dynamic spectrum of the visual brightness of Comet Bradfield 1987s analyzed by the maximum entropy method with 30 days window. The abscissa is the period in day unit, and the ordinates is the power spectral density.

could come to the sunlit sphere by the change of the geometrical condition after December.

Because the only 6-day period is detected in the analysis, there are two possible cases of relating this 6-day period to the rotational motion of the nucleus. The simplest case is to assume that the rotational motion of the nucleus has no precession. When the direction of angular momentum vector coincides with the principal axis of the nucleus, no precession occurs under torque-free condition.

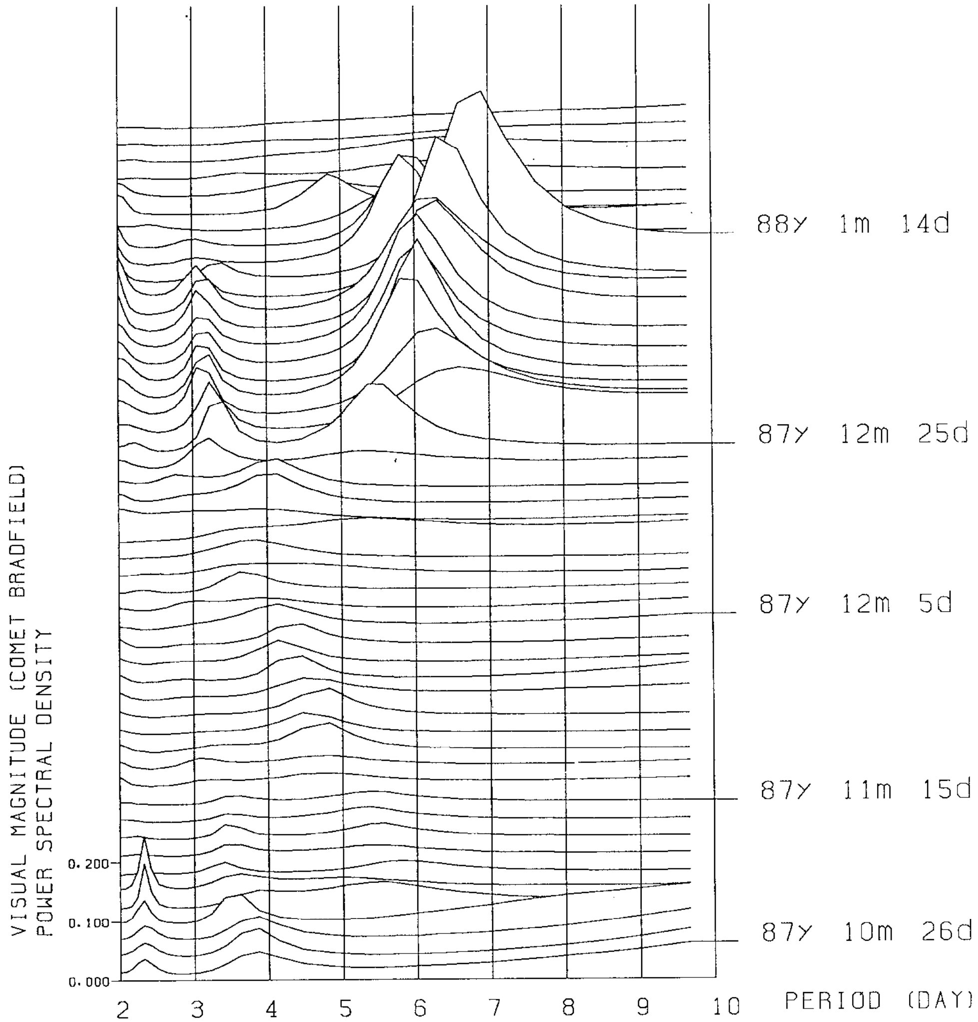

Fig. 3. The same as Figure 2 but of the data obtained by the Sidgwick's method only.

In this case, the rotational motion of the nucleus is about 6-day. Another is the case that the precession of the large amplitude exists. Two independent periods can be observed in this case. It is widely known that Comet P/Halley showed two periods of 7.4-day (Millis and Schleicher, 1986) and 2.2-day (Kaneda *et al.*, 1986). This is thought to be the result of the rotation with the precession. Although we found 6-day period only, we cannot reject the latter possibility because this study used only the brightness variation data sampled at each 24 h. Many kind of observations must be needed for comprehensive understanding of the rotational motion of the cometary nucleus. Unfortunately, a lack of the observations of this comet, especially near-nucleus imaging and precise photometry, prevented us from the more analysis on the rotational motion of the nucleus.

Sekanina (1981) suggested the practical impossibility of eliminating contamination by the coma and unpredictable short-term variations in comet activity that are not necessarily associated with rotation even if the precise photometry. However, Fay and Wisniewski (1978) succeeded to find out the brightness variation of Comet P/d'Arrest with a period of 5.17 h from photoelectric photometry. Moreover, in the recent apparition of Comet P/Halley, two different periods are discovered on the analysis of the photometric brightness. Therefore, the brightness measurements of the comet turns out to be effective for determining the rotational or precessional period. It is true that the total visual magnitude estimates are not as precise as the photometric or the photoelectric photometry. However, the large amount of the amateurs' data with a long time-span can overcome the defect of inaccuracy. In this meaning, amateur-professional cooperation must be needed for the future of cometary research, as the resolution proposed by the Executive Committee of the 20th General Assembly of the International Astronomical Union.

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